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ARCTIC SNOWMOBILE DEVELOPMENT:
LIGHTWEIGHT MATERIALS RESEARCH
FOR SUSPENSION SYSTEMS AND FLOTATION

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by

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Nunasi Corporation

for the

Transportation Development Centre

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17. Abstract

This development project had three objectives: upgrading the suspension system of the SAMAK 428 arctic snowmobile; examining the potential of lightweight composite materials; and, studying options for achieving flotation with snowmobiles.

A progressive-rate rear suspension was designed and successfully tested on a SAMAK 428 prototype.

An entirely new proof-of-concept prototype was constructed using composite materials and aluminium. All components are integrated into a fibreglass-reinforced-plastic sandwich containing structural foam. New features include independent front suspension, progressive-rate steering and a single cylinder engine. The prototype weighs 136 kg, 30 kg less than a comparable long-track machine.

Three methods of flotation were investigated: sealed hull, inherent buoyancy and inflatable release. Two objectives were addressed: driver safety and retrieval of the machine. Inherent buoyancy was considered the most practicable, and was achieved with the lightweight prototype. Test in a swimming pool showed that it could support the driver clear of the water.

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17. Résumé

Ce rapport traite des travaux de développement de la motoneige arctique SAMAK 428 et des trois objectifs fixés à la recherche: améliorer la suspension, étudier les possibilités offertes par les matériaux composites légers et assurer la flottabilité du véhicule par une technique appropriée.

Une suspension arrière à flexibilité variable a été conçue et essayée avec succès sur un prototype.

Une version allégée construite en matériaux composites et en aluminum a été réalisée en prototype. La nouveauté de la réalisation est que tous les éléments sont intégrés dans une structure sandwich en matière plastique renforcée de fibres de verre et remplie d'un matériau expansé. Le prototype est caractérisé par une suspension avant indépendante, une direction à action progressive et un moteur monocylindre. Il ne pèse que 136 kg, soit 30 kg de moins qu'une motoneige à chenilles longues comparable.

Trois techniques ont été étudiées pour assurer la flottabilité: coque étanchéisée, flottabilité inhérente et coussin gonflable, avec pour objectifs la sécurité du conducteur et la récupération de la machine. Plus facile à réaliser, la technique de la flottabilité inhérente a donné de bons résultats sur le prototype allégé. Un essai en piscine a démontré que celui-ci peut supporter le conducteur hors de l'eau.

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SUMMARY

The project had three objectives:

1. To re-design the front and rear suspensions of the Samak 428 prototype Arctic snowmobile

2. To investigate the substitution of advanced lightweight materials for the metals used in conventional snowmobiles.

3. To investigate the potential for achieving vehicle flotation in water with such lightweight materials

Inuit hunters had tested the first series of prototypes and their suggestions for improvements were incorporated in this second series. They included:

1. Larger skis, with longer wear bars and larger grips.

2. Higher ground clearance, through using a deeper spring arch.

3. Longer rear suspension travel: 12 cm - compared to 9.5 for closest comparable utility machine.

4. Two more idler wheels added to the rear suspension.

5. A progressive effect incorporated into the rear suspension action.

6. Rear suspension modified for rapid dissembly.

For the lightweight materials research segment, it was decided to design and construct an entire, proof-of-concept prototype. Compatibility with the Samak 428 was obtained by using the tunnel of that machine as the basis for a mould for the lightweight prototype. That tunnel was then extended to include the engine compartment as one solid unit, formed by upper and lower fibreglass shells injected with structural foam. At stress points, this basic frame was reinforced with kevlar and aluminium. The hood was made from fibreglass reinforced plastic; the windshield from Lexan.

GSM took advantage of this development opportunity to design two features not included in the initial specifications. A progressive rate steering mechanism that aims at reducing the effort required to turn in rough terrain. An aluminium, torsion-bar independent front suspension

The rear suspension closely resembled that for the Samak 428, but was fabricated mainly from aluminium. A lighter version of te Samak 428 track was specially produced by Yokohama. The skis were fabricated from Kevlar, carbon fibre, epoxy resin, structural foam, with aluminium inserts in high stress areas. This was designed both to lighten the load placed on the snow surface and to provide positive buoyancy for water flotation.

The engine is a 220 cc, 20 HP Cuyuna - a single-cylinder version of the twin Cuyuna used in the Samak 428. The engine mount was designed to accept both engines.

The weight of the proof-of-concept prototype was 136 kg, compared to the target weight of 125 kg. However, this machine was overbuilt and substantial weight reduction could be achieved in a later version, particularly if a leaf spring suspension is used. But the prototype is still considerably lighter than the 172 kg of the comparable Yamaha Longtrack Bravo.

Theoretical comparisons were made of three approaches to achieving flotation in an emergency caused by the snowmobile breaking through the ice: sealed hull, inflatable release, inherent buoyancy. The complexities and limitations of the first two in an Arctic operating environment were concluded to be such that it was decided to first explore the potential for inherent buoyancy.

The lightweight prototype was placed in a swimming pool. Without a rider, it floated high in the water. With seated rider the machine still rode high enough for the rider to be able to draw his legs clear of the surface - a critical need in Arctic waters. Moreover, the snowmobile was stable enough to enable the rider to stand on the running boards. Though the prototype was designed as a single-person machine, it was found that it would also keep two people afloat, though they were not able to keep entirely clear of the water. In all these tests, the proof-of-concept prototype exceeded design expectations.

The engine continued running for a brief period while the snowmobile was floating, but was easily re-started after the test. It appeared that only a few modifications would be needed to keep the engine running for longer. Also, a small impelling device added to the rear idler wheel could be used to obtain forward motion. This, along with other suggestions for further development, concludes the report.

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1. PROJECT CHRONICLE

1981-82 Under contract to the Transportation Development Centre, Peter Poole was asked to conduct a user and industry study of the region north of the tree-line and to consider the possibility of developing a machine more suited to northern needs. The TDC call for tender was precipitated by memoranda from the Science Advisory Board of the Northwest Territories commenting upon the unsuitability of available snowmobiles. The Study Report:

"Concluded that the economic/design problems posed by present methods of mass production might be circumvented by evolving a production process viable for local, small-scale manufacture. An investigation into the feasibility of such a course of action was recommended as a follow-up to this study. It was further suggested that this be undertaken as a collaboration between a team of engineers and representative Inuit organisations."

(Source: Snowmobiles as Utility Vehicles in the Arctic: Current Performance and Prospects for Improvement. Transport Canada, TP 3728E, 1982)

1983-84 Nunasi Corporation submitted a proposal to the Transportation Development Centre to conduct the Design Study. A team of engineers integrated the user comments obtained in the first study into a set of design options. These options were presented to the hunters of Kangiqsualluujjuac, Arctic Quebec. These consultations led to the specification of a single design and the recommendation that prototypes be constructed and tested.

At the final community meeting on this project, the hunters invited Nunasi to test the prototypes on their land - as they had access to a wide variety of northern terrain: sea-ice, tundra, soft forest snow.

(Source: Arctic Snowmobile Design Study. Transport Canada, TP 5498E, 1984)

1985-86 With support from Transport Canada, the Eskimo Loan Fund and Special ARDA, two prototypes were constructed by GSM and tested in Kangiqsualluujjuac. One prototype was left behind to be passed amongst the hunters, and their comments were recorded. The Project Report commented that, in general:

"Local hunters approved of the impact resistance and pulling power of the machines. Design recommendations were provided which will be incorporated in the next generation of prototypes."

The Report recommended:

"the construction of a series of pre-production prototypes coupled with a program of training and technology transfer directed towards eventual northern fabrication and assembly."

The Report also reviewed the prospects for improving the design of twin-track snowmobiles - which had not made any significant advances since the 1960's. On their own initiative, GSM engineers developed renderings and constructed a concept-testing prototype.

(Source: Arctic Snowmobile Prototypes.
TP 7760E, Transport Canada, 1986)

1986-87 With support from the Native Economic Development Program and the Eskimo Loan Fund, a series of ten Samak 428 pre-production prototypes have been built. Construction was concentrated in-house, allowing GSM to develop tooling suitable for small-scale production in parallel with the development of the machine itself.

This prototype was briefly tested at Iqaluit in the spring of 1987 and performed well in pulling trials. The prototypes are now being prepared for full winter trials in 1987-88.

At the same time, the Transportation Development Centre has provided support for Nunasi and GSM to develope a single-cylinder, lightweight, experimental prototype which will explore the scope for substituting composite materials for metal in the main frame elements. This objective emerged after the Samak 428 was exhibited at the Toronto Native Economic Summit in 1985 and Indian groups used to softer snow conditions expressed an interest in a lighter, high-flotation snowmobile.

Thus, at this stage, there are prototypes at three phases of development.

2. PROJECT OBJECTIVES

The project had three objectives. One: to complete development work on the Samak 428 - before proceeding to the stage of production research funded from a different source. Two: to commence work on an entirely new concept in snowmobile construction, maximising the structural application of new materials. Three: to investigate the potential for flotation with the lightweight materials. Specifically, these objectives were:

2.1. Samak 428 Suspension

To re-design the front and rear suspensions according to the results of Arctic field trials of the first prototype series and the recommendations of the Inuit hunters who collaborated in these trials. Specific objectives were:

- Longer travel: 12 cm (rear)
- Progressive effect (rear)
- Extra idler wheels (rear)
- Rapid disassembly (rear)
- Higher ground clearance (front)
- Improved ski form (front)

2.2. Lightweight Materials Research:

To investigate the potential for substituting a variety of lightweight materials for the metals commonly used in snowmobile construction. These materials include:

- fibreglass (FRP)
- structural foam
- Kevlar
- carbon fibre
- aluminium
- epoxy resins
- polyester resins
- ABS nylon alloys

2.3. Flotation

To conduct a theoretical investigation of options for developing a snowmobile that will float in emergency situations, concentrating on three approaches:

- sealed hull
- inherent buoyancy
- inflatable release

3. SAMAK 428 SUSPENSION

During the winter of 1986-87, two first series prototypes were tested in the Inuit community of George River, Quebec. After GSM engineers had completed their tests, one machine was left behind for the hunters to use in the normal course of their work. Their comments were relayed to GSM and used in improving the front and rear suspension for inclusion in the Samak 428 prototype series.

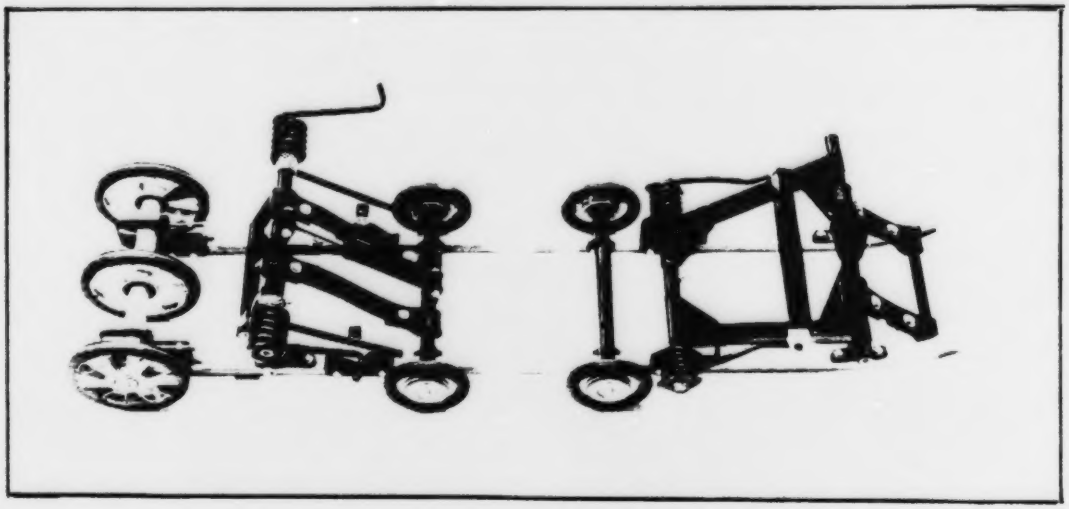
Most of the re-design effort was concentrated upon the rear suspension. For the front, the suspension travel was left at 9.5 cm - equivalent to comparable machines - but ground clearance was increased from 13 cm to 17.5 cm by installing a deeper spring arch. The first set of skis was replaced by a slightly larger unit, with longer wear bars and and larger hand grips at the front end.

It was expected that the increased travel and ground clearance would make the snowmobile less stable, but a slight increase in ski stance neutralised this tendency and field tests revealed that the new system was equivalent or better than the Yamaha ET 340 in terms of stability.

The rear suspension attaches to the tunnel at four points. By unfastening four bolts, the entire suspension can be removed more quickly than that of any other snowmobile. This is regarded as a valuable feature. Owners often neglect minor maintenance and replacement tasks because of the effort requred to extract the suspension system.

The new suspension was field tested in Iqaluit in the spring of 1987. It performed well in fairly deep fresh snow and on rough sea ice. Many of the local residents who tried the prototype approved of the simple, tough layout and the utility features such as the grease nipples on axles and idler wheels.

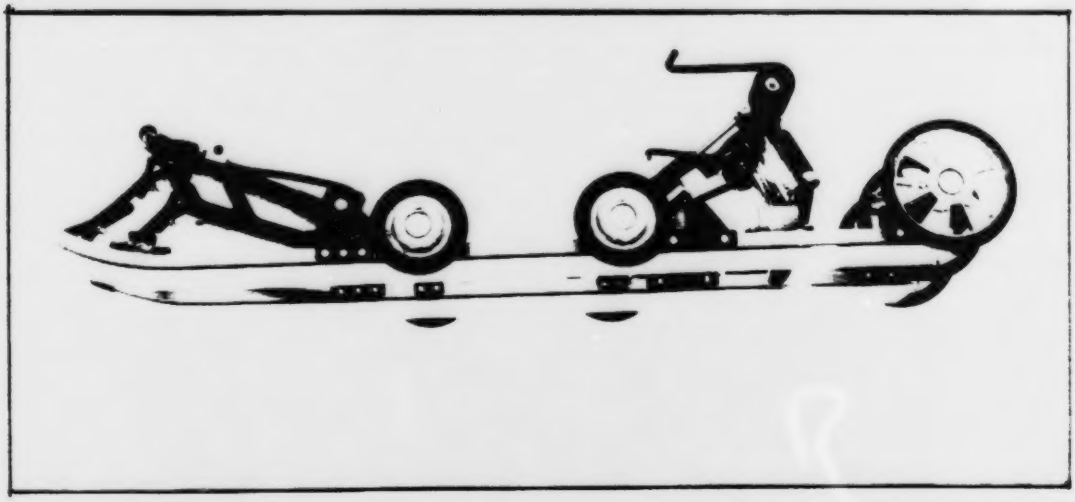
On the following pages, the improvement to the suspension system are illustrated and briefly described.

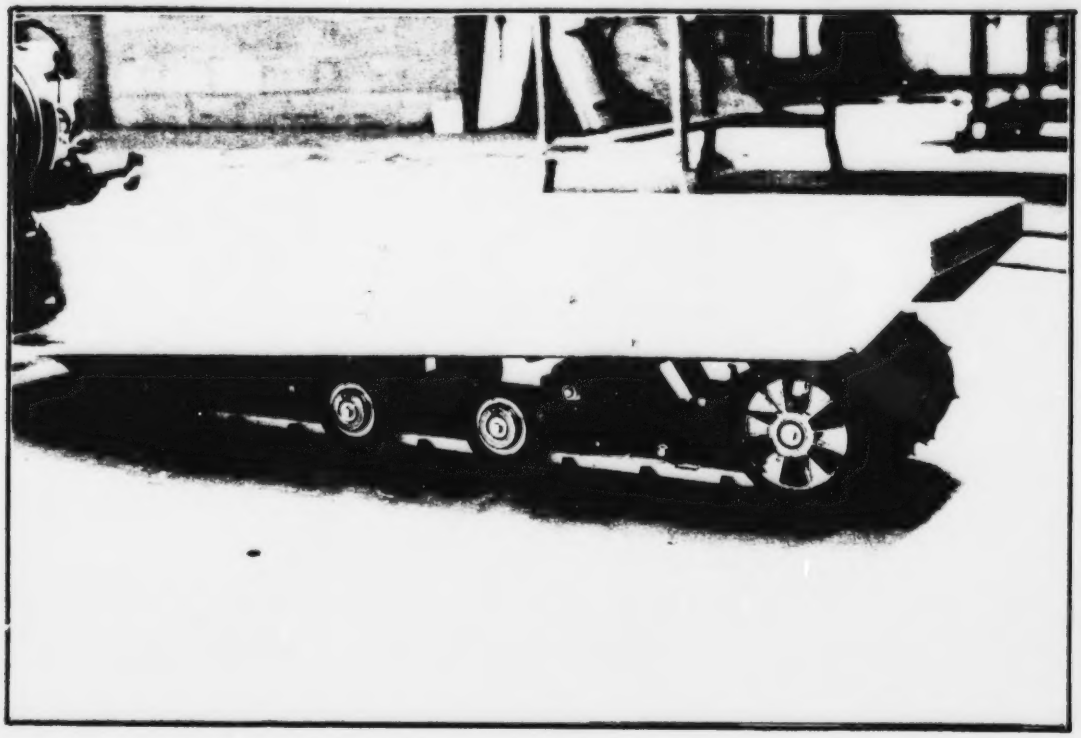


To maximise the potential for in-house fabrication and northern assembly, all of the mounts, cross members, axles, straps and snubbers were fabricated in-house by GSM Production.

The slide rails were produced by Reynolds Aluminium, using a die designed specifically for this application. The springs were obtained off-the-shelf and modified in-house. Hi-fax and wheels were purchased off-the-shelf.

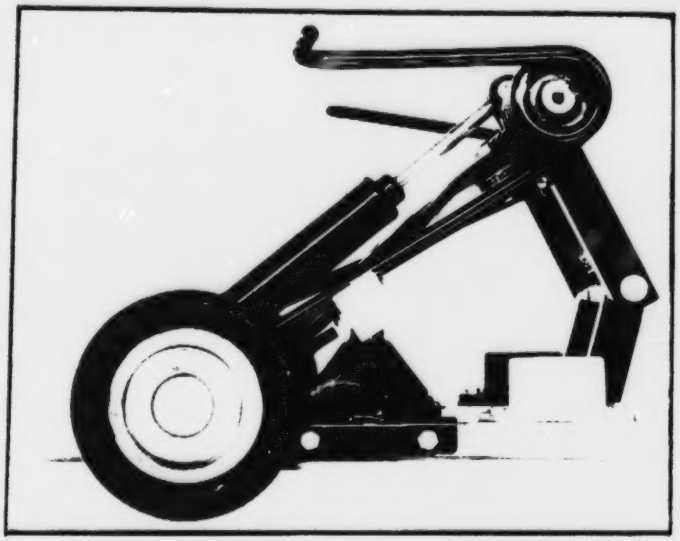
The weight of the rear suspension is 26 kg (equivalent to that of the Yamaha ET 340).





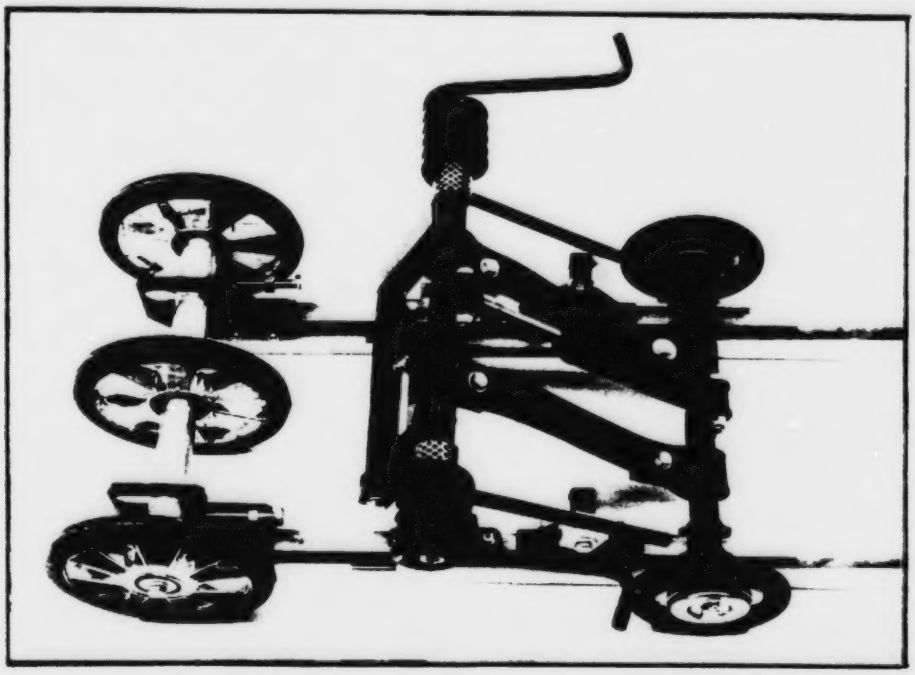
Following the Arctic field trials, and the suggestions of Inuit hunters, the rear suspension travel was increased from 9.5 cm to 12 cm.

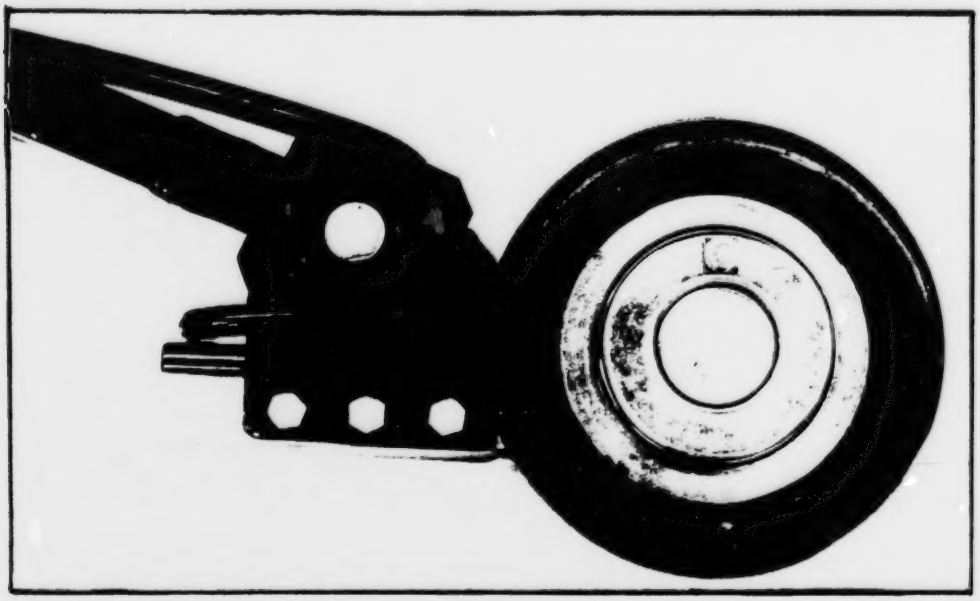
The travel for comparable machines is 5.0 cm for Yamaha and 9.5 cm for Bombardier.



A progressive suspension rate was achieved through using the simplified knee-joint illustrated above. Yamaha employs a similar system. Bombardier does not use progressive rate.

Note below the third (central) idler wheel installed to maintain a flat track profile. Other snowmobiles do not have this feature.

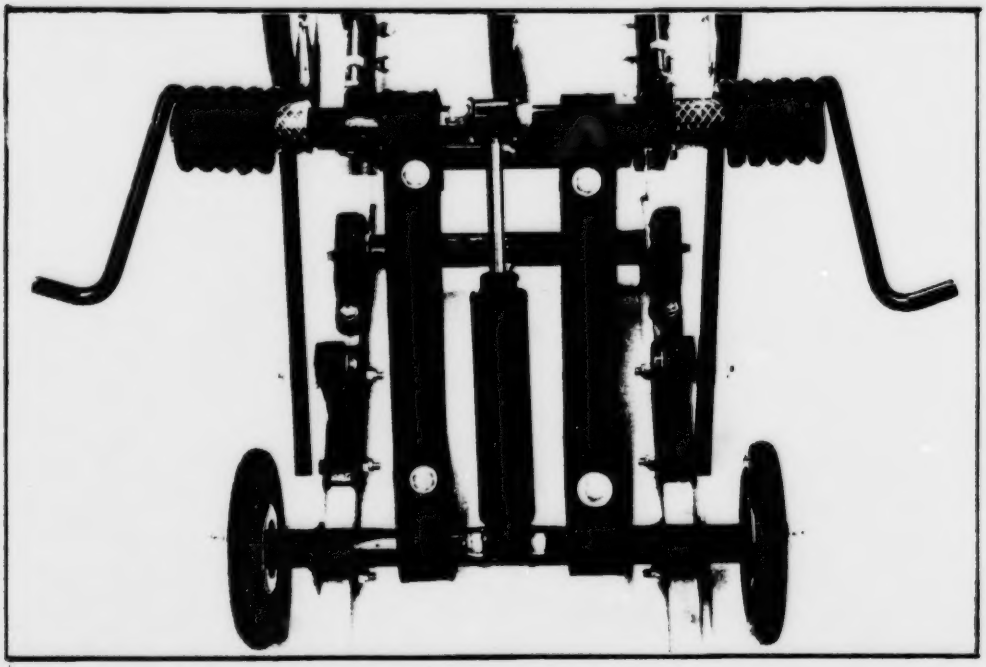




All idler wheels, cross-shafts and axles are fitted with grease nipples, unlike any other snowmobile.

Rubber snubbers are used above and below the front and rear cross members.

Like Yamaha, the sliders can be changed by removing a single bolt. On Bombardier all the wheels must first be removed.



4. LIGHTWEIGHT MATERIALS RESEARCH

The objective of this research was to investigate the potential for reducing the weight of individual components of the Samak 428 by using lighter materials. The Detailed Statement of Work called for these modified components to be attached for evaluation to one of the existing Samak 428 prototypes.

GSM and Nunasi decided instead to design and construct an entirely new proof of concept prototype. Since the main steel structure of the Samak 428 would itself be fabricated from lightweight materials, it made sense to adopt a fresh approach to total vehicle configuration that was consistent with this application of advanced materials.

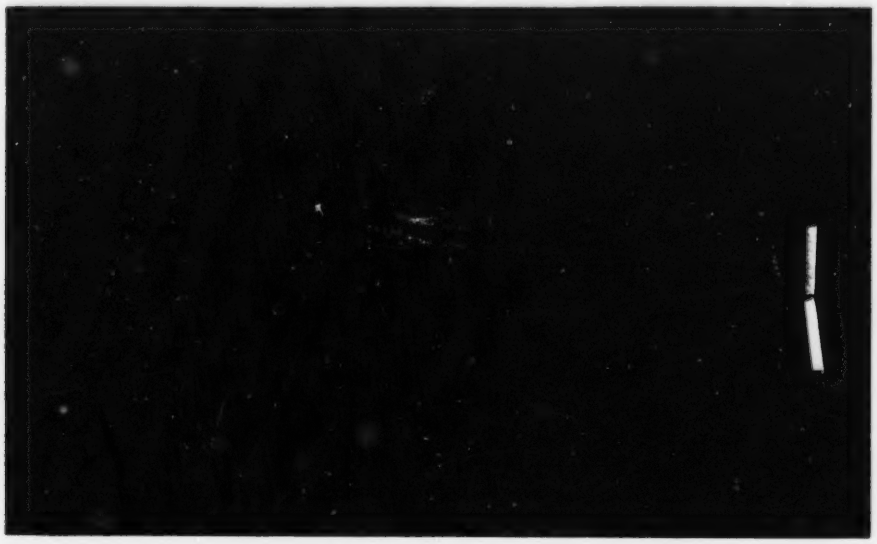
Once this approach was adopted, we decided also to design and incorporate a new independent front suspension. This followed the recommendations of several Inuit hunters who tested the Samak 428 prototypes in Iqaluit. This is not regarded as a substitute for the simple leaf spring suspension developed for the Samak 428 but is intended as a kit option which could be fitted to either model.

An additional experimental feature was developed for the lightweight prototype in the form of a progressive rate steering mechanism. This, and the other design advances incorporated in the proof of concept prototype are illustrated and described below.

4.1. Tunnel and Body

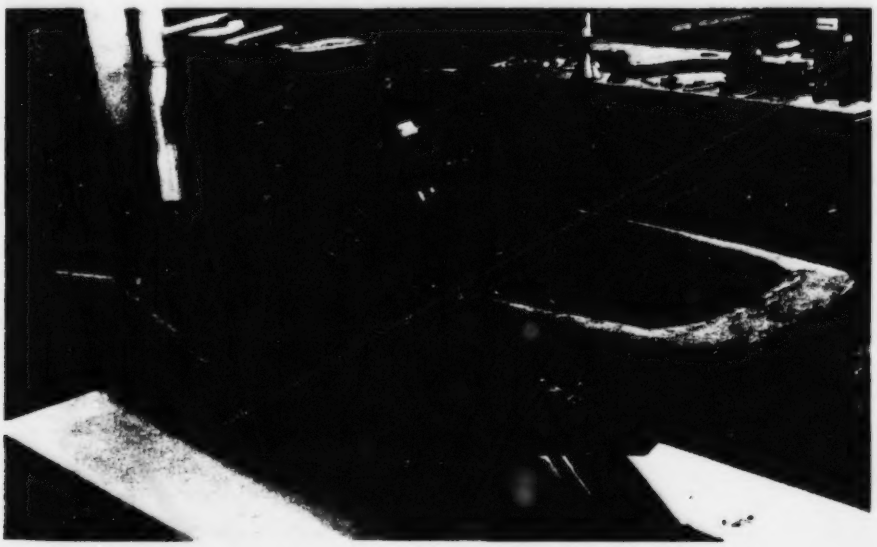
The steel tunnel from the Samak was used as a mould to form the lower element for the foam core sandwich - thus ensuring that the suspension components from the two machines will be interchangeable.

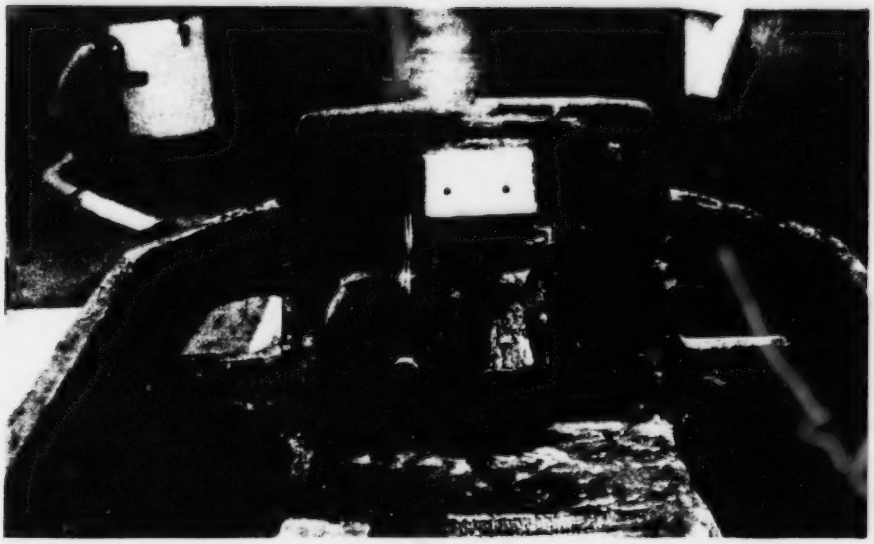
The body shape was then carved from structural foam fixed on top of the bottom element. When this was completed, the upper element was hand layed-up over the foam. In a production mode, the foam would be injected into the sandwich.



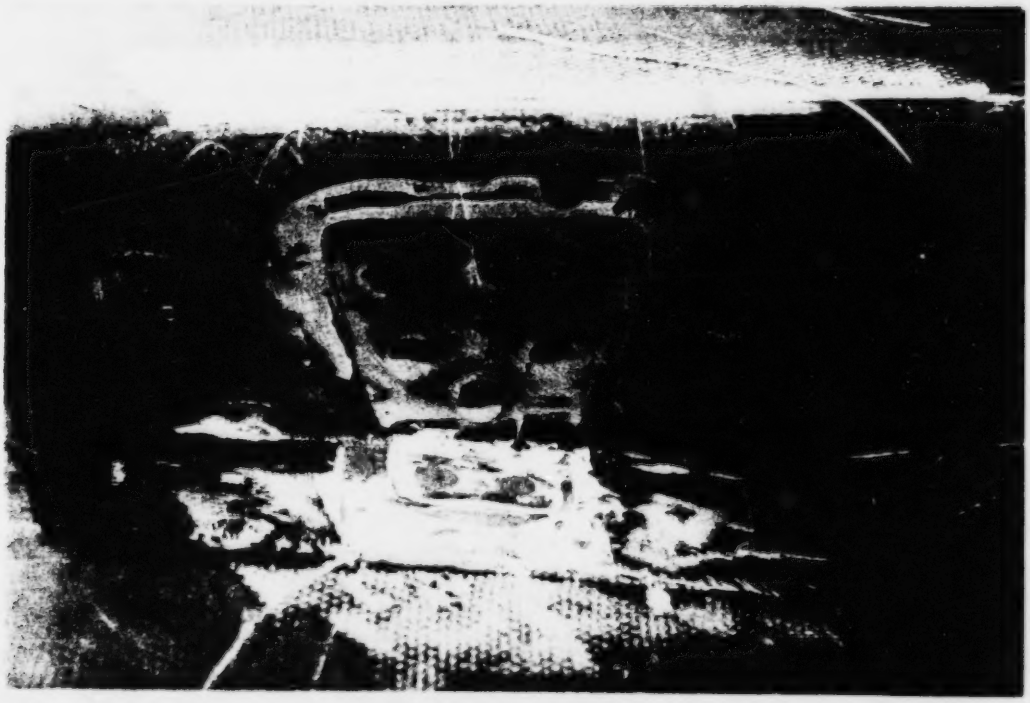
The illustration above shows the complete snowmobile body, integrating the tunnel, nose cone, side cheeks, belly pan, fuel tank and rack in a single unit. This unit is formed from upper and lower fibreglass shells injected with structural foam. The thickness varies from 3 cm in the tunnel area to 20 cm in the nose cone. The weight of this unit is 47 kg.

We expect that this weight could be reduced with further development. Also, by varying the thickness of the shell and the density of the foam, the volume could be enlarged while the weight remained relatively constant. This potential will be taken advantage of in developing flotation.

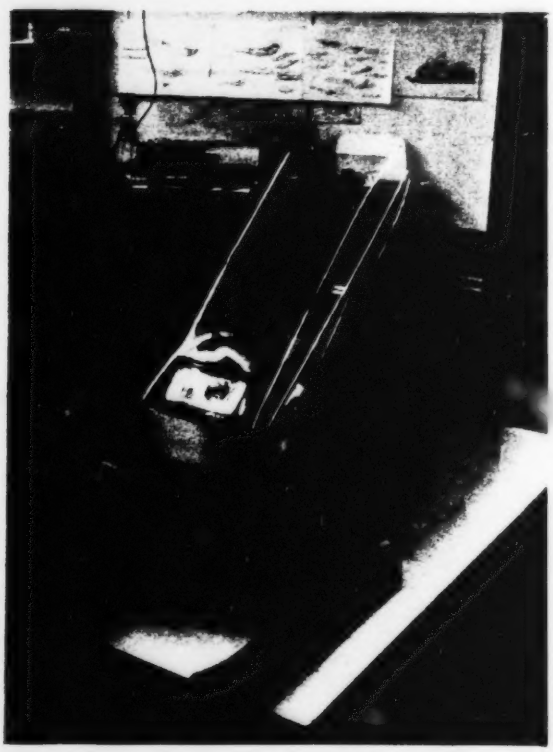




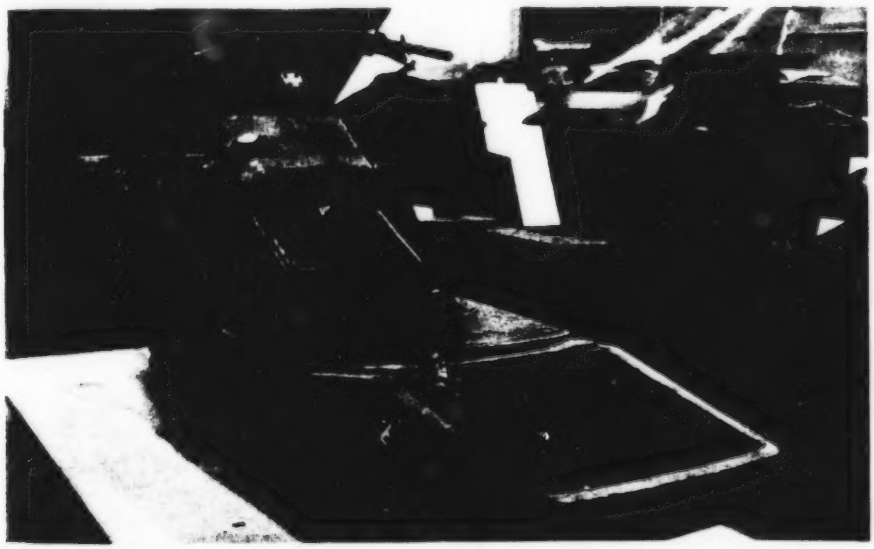
At stress points, the body is reinforced with kevlar and aluminium inserts. These include the attachment points for the rear and front suspensions and the mounting for the steering mechanism and engine.



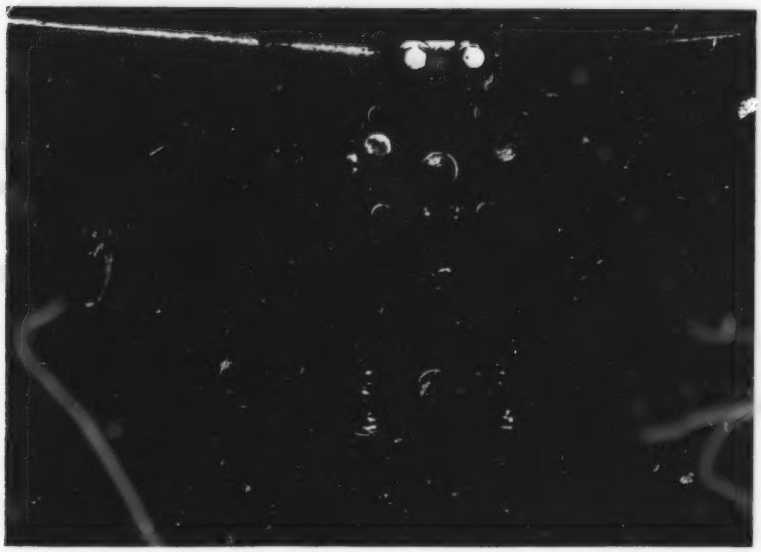
The hood is formed from fibreglass reinforced plastic. It is protective rather than structural and is extremely light. The windshield was thermo-formed from Lexan. Despite its raked appearance, the windshield on this prototype provides as much protection as the high-standing windshield on the Samak 428.



This body was layed up by hand; the most suitable process under these circumstances. However, it is not certain that this is the most effective substitute for steel. The next prototype series should compare two methods. One, is FRP produced by hand lay-up. The other is thermo-forming of a composite such as polyethelene or ABS nylon alloy.

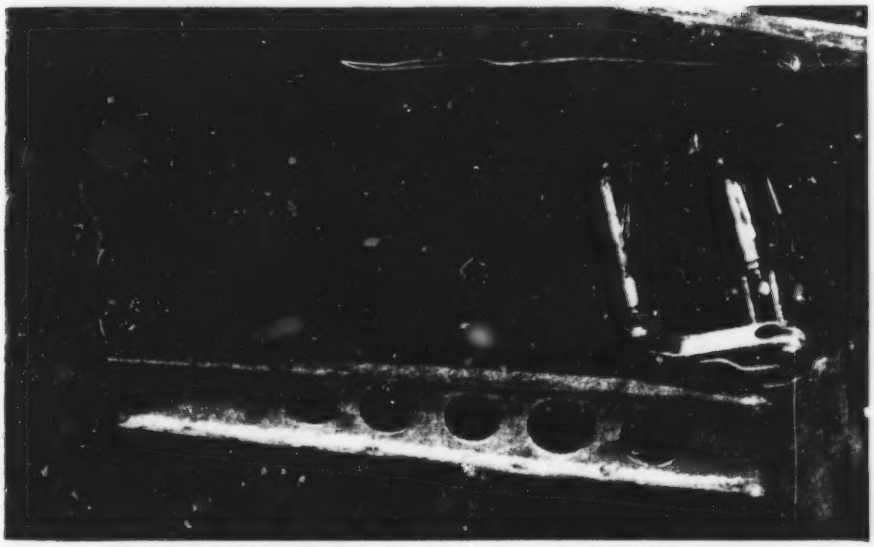


4.2. Progressive Rate Steering

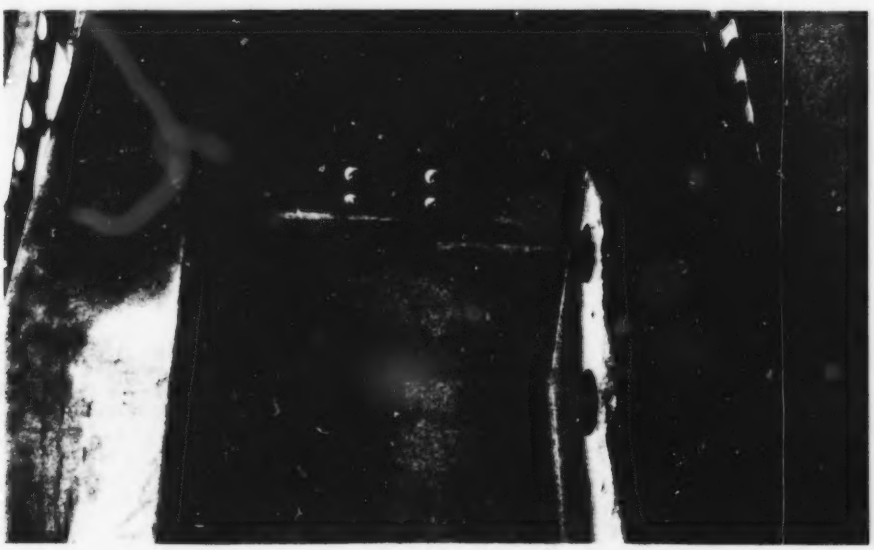


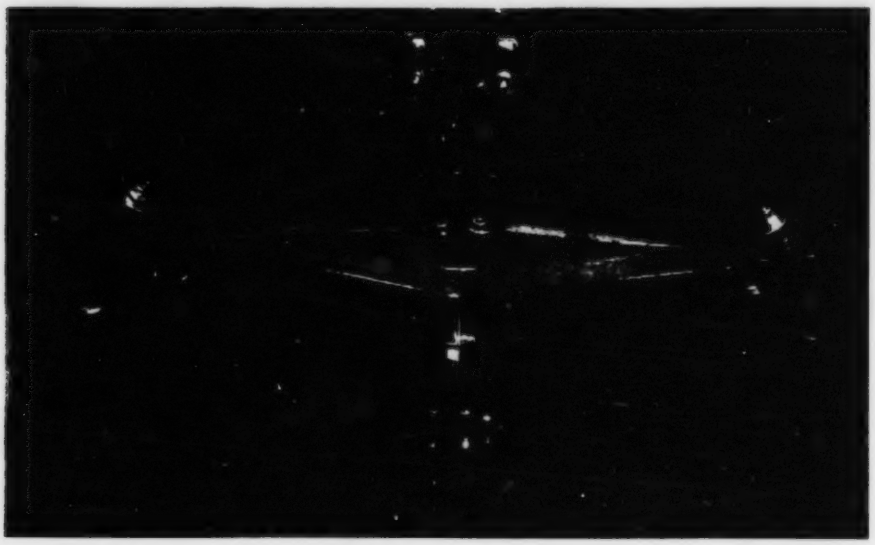
The objective is to reduce the amount of effort required to turn in difficult terrrain. As the skis are turned, the ball at the end of the steering shaft moves backward along the track, increasing the amount of leverage exerted upon the tie rods. A variant upon this mechanism is used on the Bombardier Alpine, but in a single ski application.

4.3. Independent Front Suspension



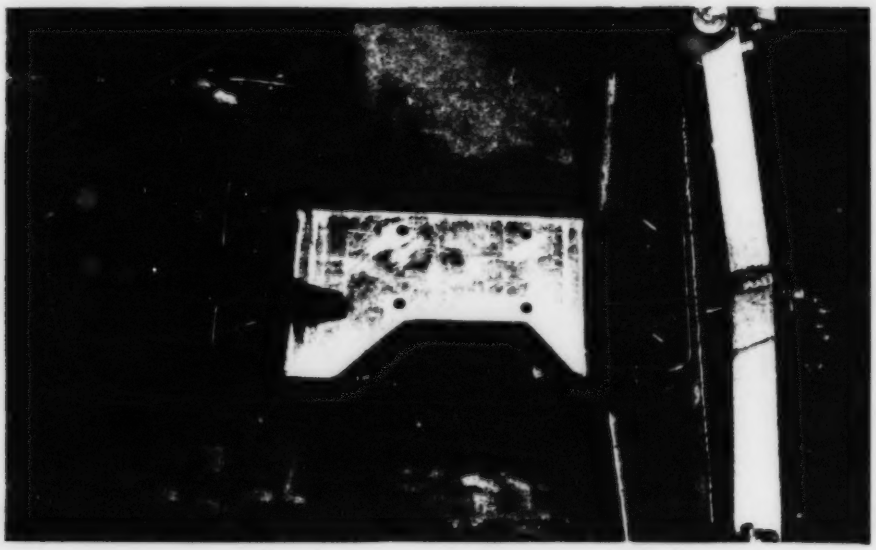
Almost all suspension components are fabricated from aluminium. Unlike other snowmobiles, the torsion bar is used as a spring rather than an anti-sway device. The torsion bar is mounted at the strongest point on the body, thus reducing the front-end stress that is the common cause of damage to snowmobiles in Arctic conditions.





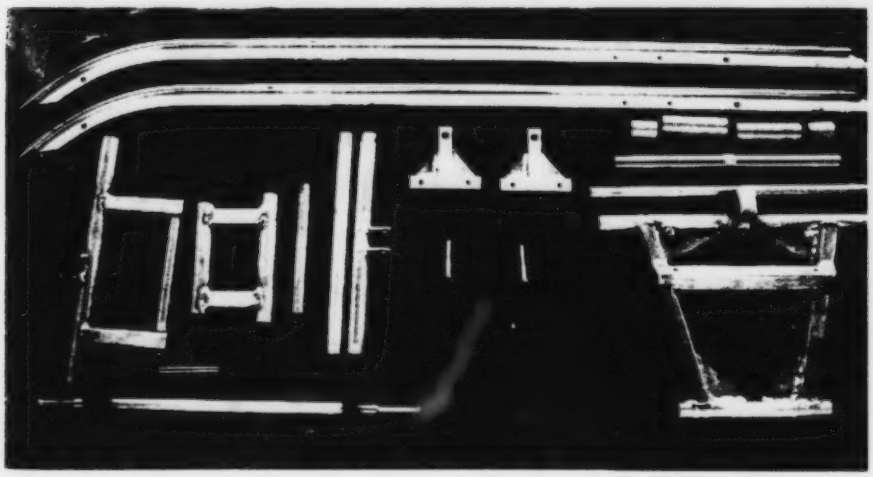
A singular feature on this suspension is the transverse seesaw, designed to transfer part of the load from one ski to the other, thus reducing the stress that would otherwise be absorbed by the machine. This mechanism is a modified version of the system used on racing snowmobiles, but is not used on other stock snowmobiles.

To further minimise the load and weight on the front end of the machine, the suspension support is integrated with the engine mount.



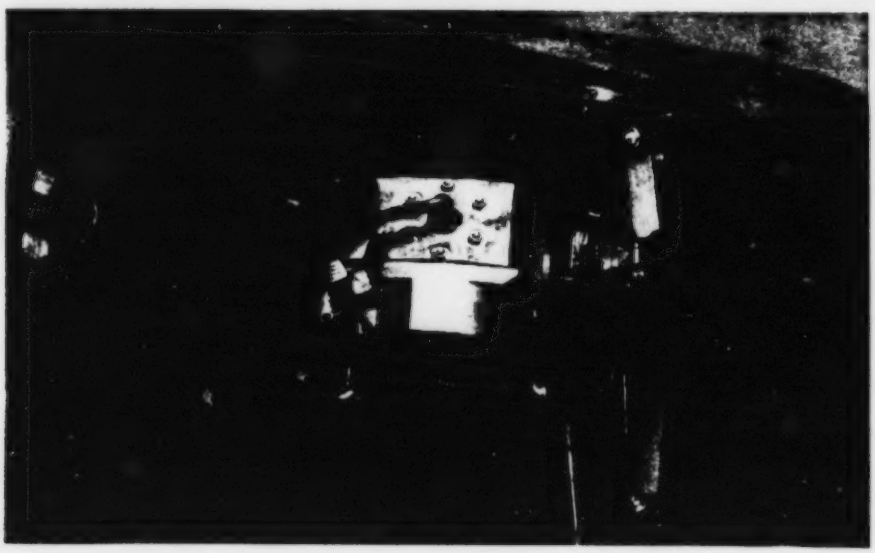
4.4. Rear Suspension

This suspension is similar in construction to that of the Samak 428. The difference for the lightweight is that most parts have been fabricated from aluminium. The track is the same length as the Samak 428 but Yokahama have provided a prototype version with fewer grousers.



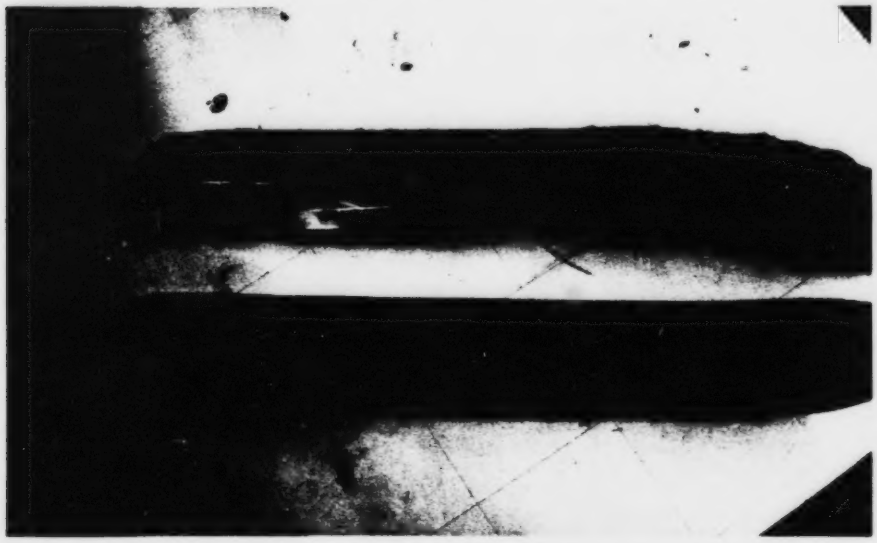
4.5. Engine

The engine is a single-cylinder 220 cc, 20HP Cuyuna, which weighs 20 kg compared to 27 kg for the Samak 428 engine. The engine mount for the prototype has been designed to accept both engines.



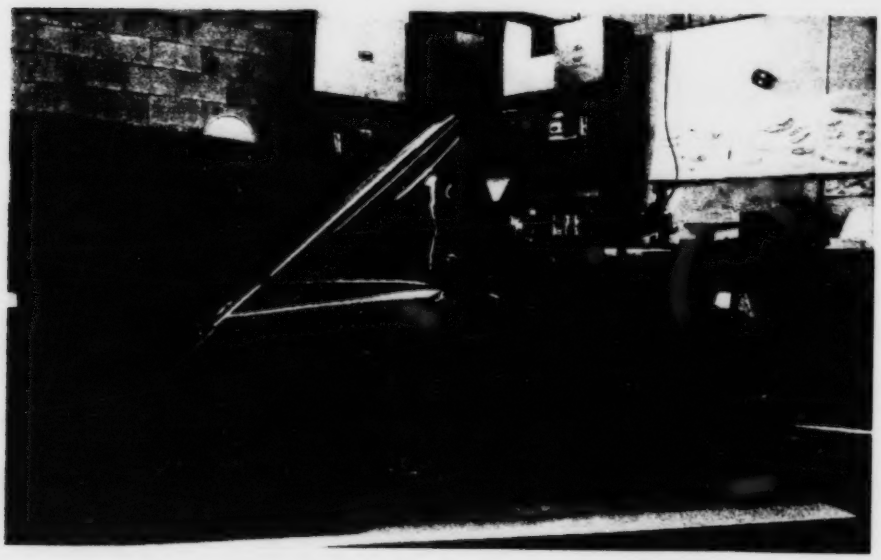
4.6. Skis

Lightweight prototype skis have been fabricated from Kevlar, carbon fibre, epoxy resin, structural foam and aluminium inserts in high stress areas. The ski illustrated here will considerably lighten the load upon the snow as well as providing positive buoyancy for flotation.



4.7. Seat

The seat is also designed to provide positive buoyancy. But instead of using a closed cell foam, a conventional open cell foam has been waterproofed with a silicone coating.



4.8. Overall Weight Reduction

The target weight for an eventual production version of this prototype is 125 kg. The weight of the proof-of-concept prototype is 136 kg. This is partly due to the materials used in the build-up process for the central structure and there is considerable scope for further weight reduction in this area once materials' testing has been concluded.

This compares with the following weights for six of the lightest snwomobiles in current production

Bomardier Elan	130 kg ...	track: 274 cm
Bombardier Citation .	134 kg ...	track: 245 cm
Samak Lightweight ...	136 kg ...	track: 332 cm
Yamaha Bravo	136 kg ...	track: 207 cm
Polaris Star	152 kg ...	track: 238 cm
Bombardier Tundra ...	163 kg ...	track: 334 cm
Yamaha Bravo	172 kg ...	track: 326 cm

The lightweight prototype is 6 kg heavier than the lightest machine on the market, the Elan, but that machine is not a long track. The lightest of the existing long track snowmobiles, the Bombardier Tundra, is 30 kg heavier than the prototype. This establishes that the Samak lightweight prototype has a lighter footprint than any existing single-track snowmobile.

The 136 kg for the lightweight compares to an overall weight of 196 kg for the Samak 428. Without the engines, both machines have comparable dimensions and running gear. If the engines are excluded, the lightweight weighs 106 kg and the Samak 428 weighs 166 kg, a weight reduction of 30%.

4.9. Conclusions

This prototype excercise has established a workable configuration for an innovative snowmobile in which all major structural metal parts are replaced by composite components. This has the potential for developing a lighter, more manoueverable and more economical snowmobile than existing types.

The weight/volume ratio for the lighweight also has significant implications for safety for there is now a very real chance that a snowmobile capable of floating could be developed from this prototype.

5. FLOTATION RESEARCH

5.1. General Observations

We should first consider the reasons for trying to achieve flotation. Is it simply to permit the recovery of the snowmobile or is it to help save the driver and others who may be seated on the snowmobile or the komatik.

5.1.1. Typical Arctic Snowmobile Emergencies

When personal safety is at stake, we should consider the typical Arctic emergency where flotation would be an advantage. A snowmobile, which may be towing a komatik containing family members, breaks through the ice. The most dangerous conditions are on the sea ice near break-up time, on unstable ice on lakes and rivers, or in estuaries or similar offshore areas subject to wide tidal fluctuations.

Once in Arctic water, survival depends upon getting out within at most two minutes; a non-swimmer hanging on to a floating snowmobile will only stand a chance of survival if he can clamber entirely out of the water or if there is someone to throw him a line within the two minute period. There is otherwise no advantage to hanging on to a floating snowmobile.

For flotation to be effective in personal survival, the machine must be stable in the water and there must be enough if it sticking out of the water for the driver to be clear of the surface. This is the most demanding case with respect both to the amount of buoyancy required and the need to deploy the buoyant material so as to achieve a stable platform. At this point,we shall not be considering the case of the komatik, plus possible passengers. That would follow from successfully demonstrating a capability to support one person.

5.1.2. Snowmobile Retrieval

The other reason for making a snowmobile float is to facilitate its retrieval. Though there seems to be no quantitative evidence, the general opinion amongst northern snowmobile users is that in most cases of snowmobile breaking through the ice, the machine sinks but the driver manages to escape this experience. Often, snowmobiles are lost in quite shallow waters and the owner may return with a grapple and try to fish it out.

When the object is to facilitate retrieval, the task is simplified and the range of options broadened. But the two cases are not exclusive in terms of flotation methodology; they simply mark the limits of a single continuum. At one extreme, the most demanding case, of keeping the driver out of the water; at the other, the easiest case, of devising a means of marking the location of a sunken snowmobile.

5.1.3. Risk-taking and Liability

Two final points should be made about producing a snowmobile that floats with the driver on board. These do not affect the technical problem of achieving flotation, but would definitely call for attention if that problem is solved.

Most drivers who take their machines into hazardous ice areas have already either made a misjudgement or have displayed a casual attitude towards the risks involved. The prospect of increased security if the snowmobile breaks through the ice may act to encourage greater risk-taking.

The second point refers to manufacturer liability. To promise flotation, without being able to control loading, or the maintenance of the flotation devices, or the number of people trying to clamber on to the machine, is to expose the manufacturer to suit in the case of fatal accidents.

5.2. Flotation Methods

5.2.1. Working Buoyancy Estimates

The work statement refers to "Arctic snowmobiles" rather than any specific model, but the calculations below refer to mid-size snowmobiles close to the Samak 428 in configuration and weight.

Flotation can be expressed in several ways:

- neutral buoyancy, when the machine is entirely submerged.
- negative buoyancy, when the machine is suspended from a floating buoy.
- positive buoyancy, when a certain proportion of the machine projects above the surface.

When the objective is retrieval, neutral or negative buoyancy is sufficient. For personal survival, considerable positive buoyancy is required, as the weight of the driver must be added to that of the machine.

The human body is so close to neutral buoyancy that 0.009 cu. metre (576 cu. in.) of encapsulated air is sufficient to provide the slight amount of positive buoyancy in water, approx. 10 kg. (21 lbs.) required for survival by Coast Guard regulations. But when, as in Arctic waters, the entire body must be out of the water, a much larger air volume is required - as in the air mattresses used to support bathers.

Similarly, the amount of air required for neutral buoyancy in a snowmobile is about 0.028 cu. m. (1 cu. ft.). This figure is based upon the weighing, while submerged, of an Arctic Cat snowmobile, slightly heavier than the Samak 428. Fully submerged, the Arctic Cat weighed 21.8 kg. (48 lbs.).

For maximum flotation of a Samak 428 snowmobile, weighing 195 kg. (430 lbs.), 0.192 cu. m. (6.8 cu. ft.) of air is required. For a driver of 91 kg. (200 lbs.), 0.104 cu. m. (3.7 cu. ft.) should be added for a total of 0.296 cu. m. (10.5 cu. ft.). This volume is considerably higher than that of the snowmobile itself -- the Samak 428 is approximately 0.170 cu. m. (6 cu. ft.).

Thus the volume of air required to float both the snowmobile and the driver clear of the water surface is approximately ten timeS that required to keep only the machine floating with neutral buoyancy.

There are three main approaches to flotation:

1. A sealed hull.
2. Inherent buoyancy.
3. Inflatable release.

5.2.2. Sealed Hull

This would provide buoyancy by sealing the engine compartment, the only significant volume of potentially sealable air on the machine.

This would precipitate several problems. Air vents would be eliminated, which would seriously interfere with the cooling of the engine (during the high-risk Spring period, engine cooling is often so difficult that drivers remove the hood entirely). Seals would be required at several points: ski legs, steering column, muffler, drive shafts - presenting economic rather than technical or operational difficulties.

The joints between the cabin and the tunnel would also have to be watertight. And, more importantly, the joint between the hood and the bottom part of the engine compartment would require a seal that survived constant opening and closing.

It is difficult to imagine that seals of this kind would survive the incessant impacts of Arctic operations without constant maintenance. Moreover, it would be difficult to periodically verify that they remained watertight without submerging the machine. For a system intended to save lives, sealing the hull does not appear to be a positive approach. A certain amount of default would appear inevitable and would, in the Arctic, quickly give the machine a poor reputation. Finally, it would certainly add considerably to the cost of the vehicle.

5.2.3. Inherent Buoyancy

This is achieved by inserting flotation material directly in the snowmobile. The most suitable material is closed cell foam and the most suitable places on the machine are the seat, the back rest and the inside surface of the engine compartment: hood, nose cone, side-cheeks.

Though the seat and back rest are the most obvious locations, there are certain drawbacks. Snowmobile seats and back rests are usually fabricated from open cell foam, formed in a mould. Closed cell foam is usually available only in sheet or block form and cannot be so easily formed in a mould. Moreover, the closed cell foam used in life jackets is harder than normal snowmobile seats and its use would expose the driver to a larger risk of back injury.

But this problem may be resolved shortly as new, mouldable, types of closed cell foam are becoming available. We shall soon be testing these to ascertain their suitablility as seat material.

5.2.4. Inflatable Release

This method would employ a compressed air container, the inflatable package and some form of trigger mechanism. The objective would either be to provide sufficient buoyancy for the driver to get clear of the water or to facilitate the location and retrieval of the machine.

5.2.5. Inflatables for Driver Survival

There is some potential for adapting the technology used in air-sea rescue packages to meet these objectives. For the trigger mechanism there are three options: a manual release, a pressure activated switch, a water-activated switch. None of these is foolproof. A manual trigger may fall beyond reach in an emergency. Pressure-activated switches require the sinking of the machine to a certain depth, which would not be consistent with driver security. Water activated switches are still under development. One company in the United States which produces search and rescue inflatables is working upon a compact battery-powered model which will have a response time of 2-3 seconds.

There is also the problem of positioning an inflatable that could be deployed for driver security. One option would be to adapt the air bag technology being developed for automobile safety, with the bag located in the space between the windshield and the top of the hood. Another would be to replace the back rest with an inflatable capable of supporting a person. One company produces such a device which, vaccum-packed, measures 41cm. x 18cm. x 8cm. (16"x 7"x 3") plus the trigger and gas container. (The same company recommends nitrogen rather than carbon dioxide for use in very cold water).

If the primary objective is driver security, the attachment of the inflatable device to the snowmobile could prove to be a liability. To meet this objective it is tempting to go the whole way and recommend the installation of a proven air-sea inflatable rescue package, which could provide security, shelter and other emergency capabilities.

5.2.6. Inflatables for Snowmobile Retrieval

This case is comparatively simple. A pressure-activated airbag is released at a certain depth and a line connects the buoy to the machine. A volume of 0.03 cu. metre would be sufficient to suspend the machine at close to neutral buoyancy. But this method would still require a combination of air bag, gas container and trigger mechanism, which would not be any more efficient than the provision of neutral buoyancy by a seat of closed cell foam. Furthermore, an inflatable released at depth may be carried by currents away from the point of entry and surface under the sea-ice.

5.3. Discussion

Of the three methods for achieving flotation, a sealed hull holds the least promise. For snowmobile retrieval, inherent buoyancy appears more promising than inflatable release - in terms of complexity and cost. But the specific demands of personal survival in Arctic waters, the need to get out of the water, call for a greater volume of flotation material than could realistically be inserted in a Samak 428.

A combined approach, in which the seat and/or backrest are used as attached buoys, opens up several possibilities. They would function in a similar manner to the Sea-Mate Search and Rescue Initiator buoys attached to tug boats. these are 0.0566 cu. m. (2 cu. ft.) in volume and are attached to the tug by 1,000 m. (3,000 ft.) lines. They automatically release when the tug sinks and float to the surface, where they are equipped to emit signals both by strobe light and radio.

The seat and back rest could be made from high flotation material and a method of fastening devised which allowed them to remain on the surface when the machine sinks - while remaining attached by lines to the machine. This would provide an effect similar to an inflatable release buoy without adding complexity in the combination of compressed air, trigger and air bag.

However, though the seat volume, of 0.064 cu. m. (2.27 cu. ft.) is more than double that required for neutral buoyancy of the Samak 428, once the seat is detached from the machine, the weight/volume ratio changes and the requirement for neutral buoyancy increases to 0.110 cu. m. (3.89 cu. ft.). To make such an approach effective, the overall weight of the snowmobile should be reduced, while the volume remains relatively constant.

While there is a physical limit to weight reduction, it is theoretically possible that as much volume as necessary could be added to acheive flotation. It makes sense to first determine the minimum weight for a snowmobile as a preliminary to deciding how much volume needs to be added to achieve specific levels of flotation. This was the primary objective of the materials research described in section 4.

5.4. Theoretical Conclusions

1. The specific requirement for survival in Arctic waters is that the driver be able to get out of the water within two minutes. This sets an objective that is far more problematic than simply achieving flotation for the snowmobile itself. While that could theoretically be attained with 0.3 cu. metre of air, achieving maximum flotation with a conventional metal machine and driver would call for approximately ten times that amount.

2. A sealed hull is an impracticable method for achieving flotation in that such a system could not be reliably maintained under Arctic operating conditions.

3. New emergency inflatable technology could perhaps be adapted to meet these objectives. However, for snowmobile retrieval, this would not be the most efficient approach. For driver survival, the integration of such technology within the machine would probably be less efficient than the simple provision of emergency kits of the kind developed for light aircraft or marine survival.

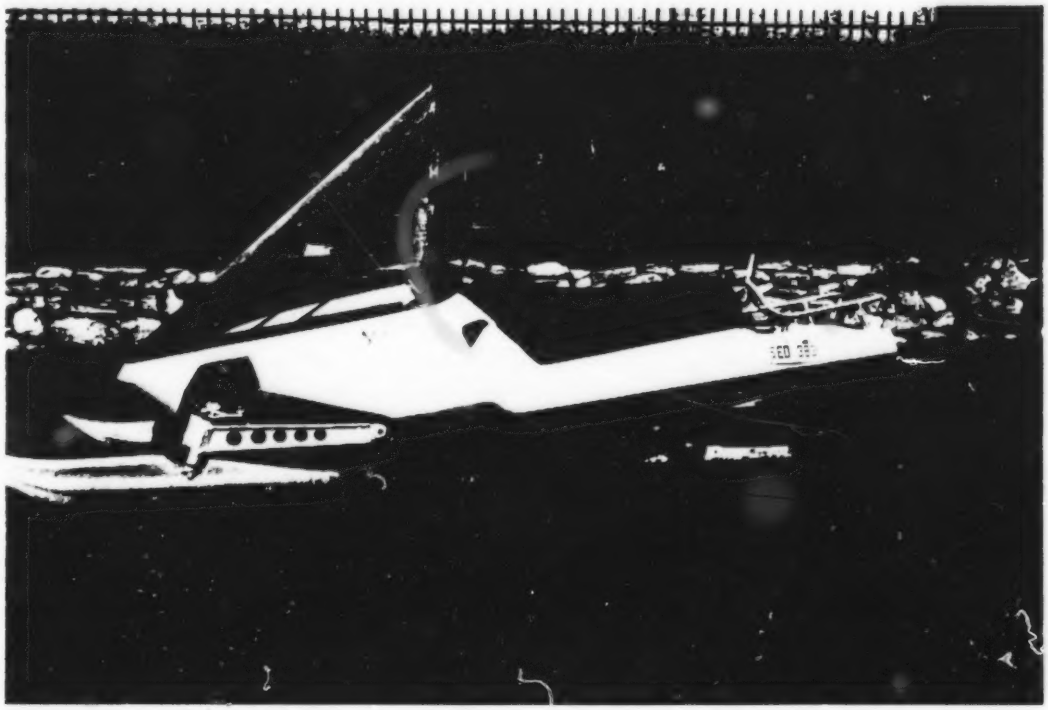
4. Inherent buoyancy is the most practicable approach, certainly in terms of snowmobile retrieval, as the amount of flotation material required to achieve neutral buoyancy is less than the volume of the seat. But, to extend inherent buoyancy to the point where the driver could be supported clear of the water would require the incorporation of a volume of flotation material approximately 1.5 times that of a metal snowmobile.

5. To avoid such a bulky construction, the more efficient approach would be to build the snowmobile from dual purpose materials possessing inherent buoyancy and also the required sufficient strength, durability and impact resistance. This design principle was adopted for the lightweight prototype.

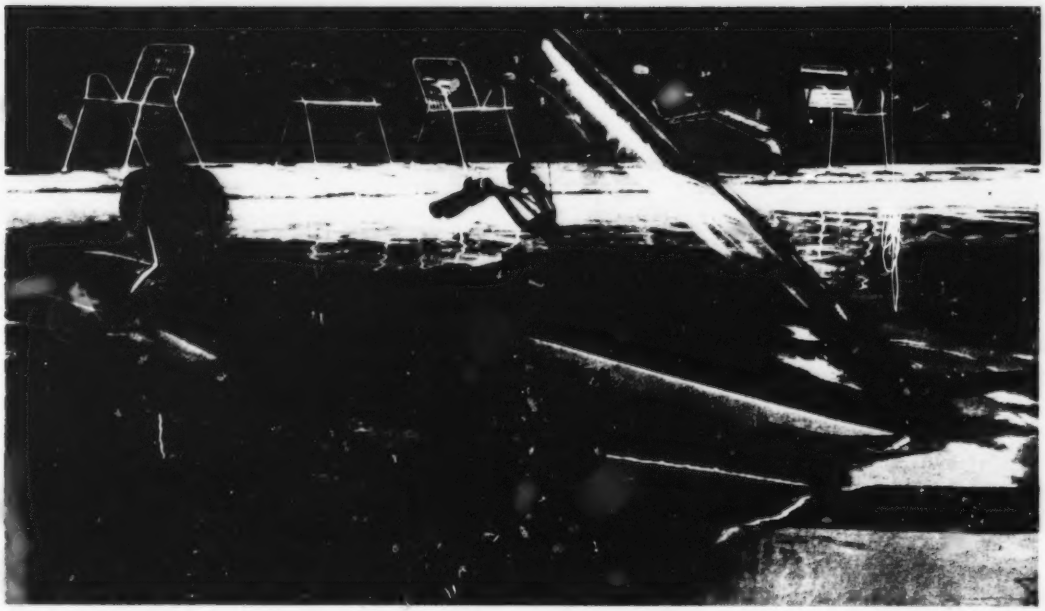
5.5. Flotation Trials

5.5.1. Swimming Pool Tests

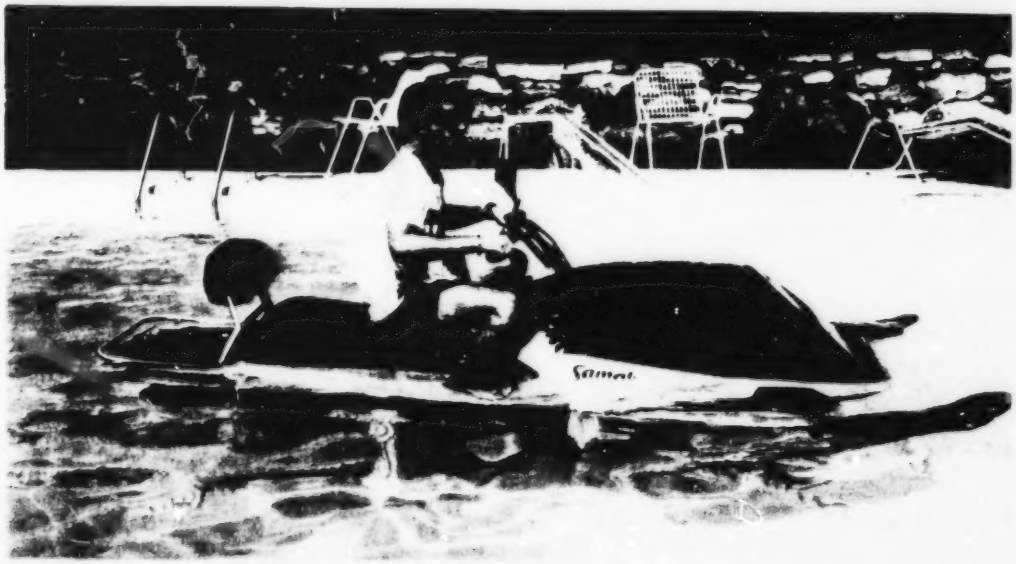
These were executed in two stages. In the first, the prototype, with a scrap engine, was placed in the water. The results were positive and in the second stage the working prototype was placed into the water under with its engine running. The results are illustrated by the following photographs.



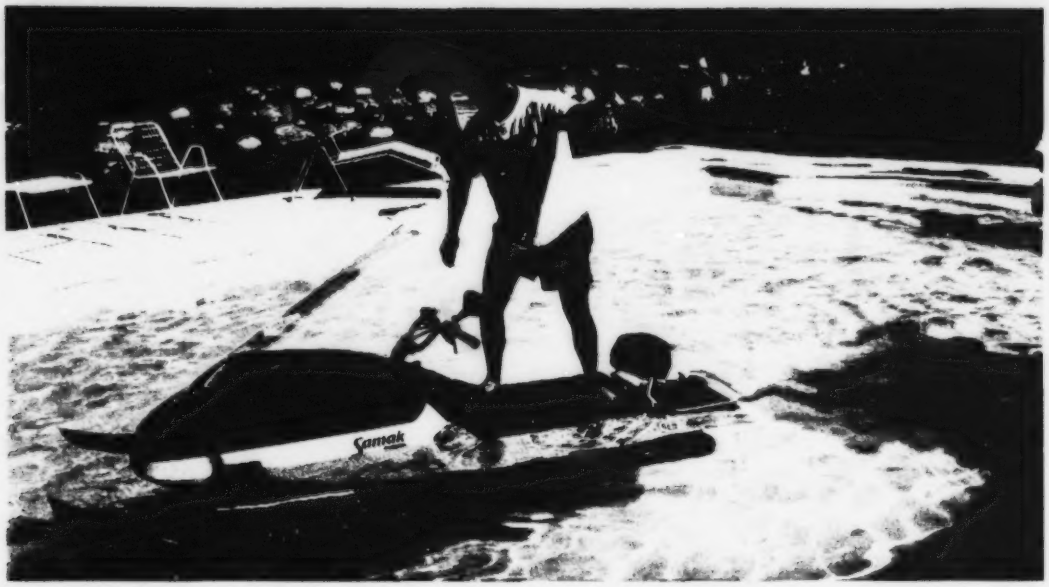
The completed prototype before the flotation test. Although the profile is sleeker than that of the Samak 428, the high, protective windshield is retained - as well as other utility attributes such as the luggage rack and the long track.



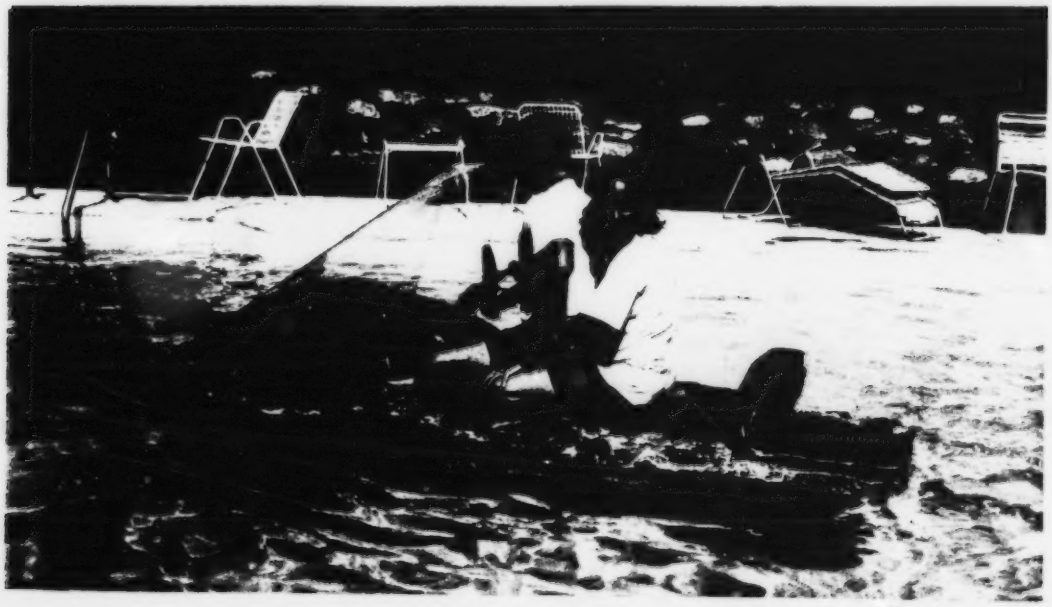
Without the driver, the machine rides high in the water. The positive buoyancy of the composite skis contribute towards achieving the generally level profile. Water is entering through the ski leg apertures, but the joint between the hood and the engine compartment is well clear of the surface.



With the driver seated, sinkage at the rear end. the engine compartment remains relatively high in the water - raising the possibility of keeping the engine running while floating.



This demonstrates excellent stability and holds promise for the development of a snowmobile that will enable a driver to keep largely clear of Arctic waters after breaking through the ice, at least in calm water.



Though this machine was not designed as a two-passenger model, this illustrates the lightweight prototype exceeding design expectations by a considerable margin. At this point, the prototype was approaching its limits to stability.

While floating, the water that seeped through the ski-leg apertures was thrown around the engine compartment by the clutch and caused the engine to stall. But, once out of the water, the engine was soon re-started.

There were indications that only a few minor modifications would be required to keep the engine running while the machine floated: silicone coating for the spark plug, a raised exhaust pipe, a raised air intake.

While the track was still rotating, there was little effect upon snowmobile movement. However, it was felt that a small impelling device could be attached to the rear idler wheels and provide forward motion in water without significantly affecting over snow performance.

5.5.2. Future Research and Development

A solid base has been achieved for further development. This could take the following lines:

COMPOSITE LEAF SPRING

Further weight reduction through the development of a composite leaf spring, as an alternative to the independent front suspension developed for this prototype. This would necessarily affect the stability and comfort of the machine, but would carry certain compensations:

- It would be inherently lighter.
- Being more compact, would leave space for a larger volume of flotation material at the front and sides.
- Fewer apertures and therefore more control of water seepage into the engine compartment.
- Simplicity, ease of repair and lower cost.

PROPULSION WHILE FLOATING

Investigate impelling devices, attached to rear idler wheels

SEAT MATERIAL

The open cell foam used for the seat slowly absorbed water. Until recently, available closed cell foams were too hard. But new materials are both softer and amenable to moulding

SEEPAGE CONTROL

Although a sealed hull is not a practicable objective, it is worth investigating the scope for delaying seepage into the engine compartment in order to keep the motor running as long as possible. This would entail testing various seals at the ski-leg apertures and hood joint.

MATERIALS RESEARCH

More work is required in comparing the performance of composite materials for, floatation, strength, impact resistance. There are significant trade-offs that should be examined in depth between, for example, FRP hand-lay-up and thermo-forming with polyethelene/ABS nylon alloy.

It is recommended that a second prototype series be constructed and tested in which these options are combined in various configurations. The results of this exercise would subsequently be incorporated in the design of a pre-production prototype series. A submission for funding for this pre-production series has already been placed with the Native Economic Development Fund. But a proposal for the next series of test prototypes has yet to be prepared.